

## DESCRIPTION

RING-OPENED POLYNORBORNENE

5

TECHNICAL FIELD

The present invention relates to a ring-opened polynorbornene, and particularly to a ring-opened polynorbornene low in birefringence, high in wavelength dependency about birefringence and excellent in 10 transparency and heat resistance.

BACKGROUND ART

Transparent resins have heretofore been used as ordinary materials for automobile parts, lighting 15 equipments, electric parts, etc., of which transparency is required, and have recently been being applied to, particularly, optical materials that optical properties are of great importance. Polycarbonate resins and acrylic resins are known as transparent resins suitably used for 20 such application fields.

However, the acrylic resins involve problems in points of heat resistance and water resistance (low water absorption property) and the like though they are excellent in transparency. On the other hand, the polycarbonate 25 resins involve such problems that birefringence is high though they are superb in heat resistance and water resistance to the acrylic resins. Therefore, as

transparent resins for optical materials, attention has been recently attracted to cycloolefin resins that have good transparency, water resistance, low birefringence, heat resistance and the like in combination and is supplied 5 to actual use.

As such cycloolefin resins, various resins have been known and described in, for example, Patent Literature 1 to Patent Literature 6.

With the high advancement of function and use of 10 optical instrument, however, these cycloolefin resins may not sufficiently satisfy properties required of optical materials in some cases. In optical materials used in optical instrument having highly advanced functions in particular, sufficiently low birefringence is extremely 15 important property. There is thus a demand for development of a transparent resin having far excellent low birefringence compared with the conventional transparent resins.

On the other hand, attention is attracted to 20 cycloolefin resins as resin materials used in optical films. Films formed of such a cycloolefin resin have been proposed as various optical films.

Specifically, phase difference plates formed of a 25 film of a cycloolefin resin are described in Patent Literature 7 to Patent Literature 10.

In Patent Literature 11 to Patent Literature 13, it is described that a film of a cycloolefin resin is used as

a protective film for a polarizing plate.

A substrate for a liquid crystal display device, which is composed of a film of a cycloolefin resin, is described in Patent Literature 14.

5 Since the optical films formed respectively of these cycloolefin resins have property that the absolute value of phase difference (birefringence) of transmitted light becomes lower as the wavelength of the transmitted light becomes longer, however, it is extremely difficult to give 10 a specific phase difference of, for example, a 1/4 wavelength to the transmitted light of all rays in a visible region (400 to 800 nm). The same circumstances apply to optical films formed respectively of other resins in addition to the conventional cycloolefin resins.

15 As described above, in resins used in application fields of which highly-advanced optical properties are required, other than a fact that they have general optical properties, the control of specific wavelength dependency about birefringence that the birefringence of transmitted 20 light becomes higher as the wavelength of the transmitted light becomes longer when a film is formed, and degree of the birefringence become great problems.

Prior Art 1: Japanese Patent Application Laid-Open No. 132625/1989;

25 Prior Art 2: Japanese Patent Application Laid-Open No. 132626/1989;

Prior Art 3: Japanese Patent Application Laid-Open No.

133413/1990;

Prior Art 4: Japanese Patent Application Laid-Open No.  
120816/1986;

Prior Art 5: Japanese Patent Application Laid-Open No.  
5 115912/1986;

Prior Art 6: Japanese Patent Application Laid-Open No.  
218726/1988;

Prior Art 7: Japanese Patent Application Laid-Open No.  
245202/1992;

10 Prior Art 8: Japanese Patent Application Laid-Open No.  
36120/1992;

Prior Art 9: Japanese Patent Application Laid-Open No.  
2108/1993;

Prior Art 10: Japanese Patent Application Laid-Open  
15 No. 64865/1993;

Prior Art 11: Japanese Patent Application Laid-Open  
No. 212828/1993;

Prior Art 12: Japanese Patent Application Laid-Open  
No. 51117/1994;

20 Prior Art 13: Japanese Patent Application Laid-Open  
No. 77608/1995;

Prior Art 14: Japanese Patent Application Laid-Open  
No. 61026/1993;

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#### DISCLOSURE OF THE INVENTION

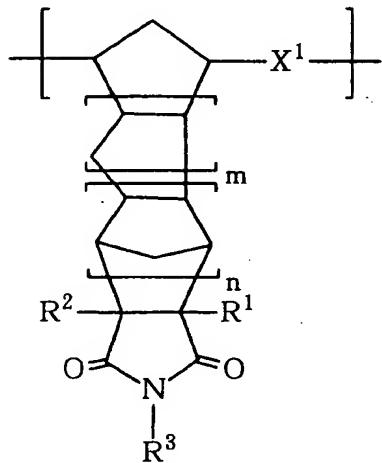
The present invention has been made on the basis of  
the foregoing circumstances and has as its object the

provision of a ring-opened polynorbornene that is relatively low in birefringence, has specific wavelength dependency about birefringence and is excellent in transparency and heat resistance.

5 According to the present invention, there is thus provided a ring-opened polynorbornene comprising a structural unit (I) represented by the following general formula (I):

[Chemical formula 1]

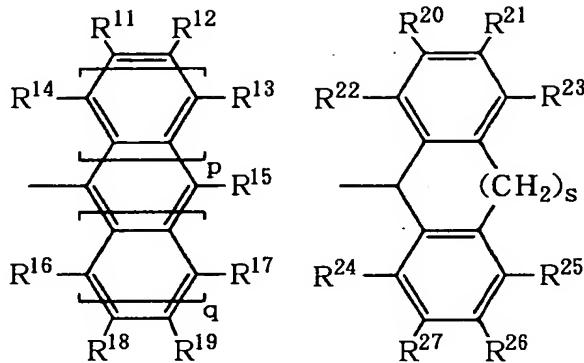
10 General formula (I)



wherein in the general formula (I), m and n are, independently of each other, an integer of 0 to 2, X¹ means an ethylene or vinylene group, R¹ and R² denote, 15 independently of each other, a hydrogen atom or a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, and R³ represents a group represented by the following general formula (I-1) or a group represented by the following general formula (I-2):

[Chemical formula 2]

General formula (I-1)      General formula (I-2)



wherein in the general formulae (I-1) and (I-2), R<sup>11</sup> to R<sup>27</sup>  
 5 denote, independently of one another, a hydrogen atom; a halogen atom; a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, which may have a linkage containing or not containing oxygen, sulfur, nitrogen and/or silicon atom(s); or a polar group, p and q in the  
 10 general formula (I-1) are individually 0 or a positive integer, with the proviso that when both p and q are 0, R<sup>12</sup> and R<sup>15</sup>, or R<sup>19</sup> and R<sup>15</sup> may be bonded to each other to form a carbon ring or heterocyclic ring, and the carbon ring or heterocyclic ring may be either a monocyclic structure or a  
 15 polycyclic structure, and s in the general formula (I-2) is 0 or an integer of 1 or greater.

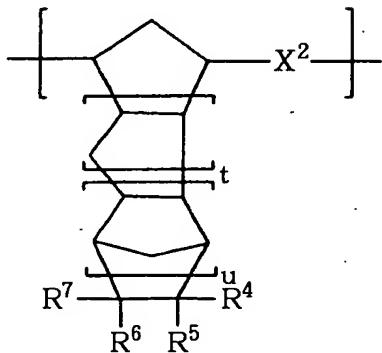
The ring-opened polynorbornene according to the present invention may be that comprising a structural unit represented by the following general formula (II).

20 In such a ring-opened polynorbornene, the proportion of the structural unit (II) may preferably be at most 98

mol% based on the whole structural unit.

[Chemical formula 3]

General formula (II)



5 wherein in the general formula (II), t and u are, independently of each other, 0 or a positive integer,  $X^2$  means an ethylene or vinylene group,  $R^4$  to  $R^7$  denote, independently of one another, a hydrogen atom; a halogen atom; a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, which may have a linkage containing or not containing oxygen, sulfur, nitrogen and/or silicon atom(s); or a polar group, with the proviso that  $R^4$  and  $R^5$ , or  $R^6$  and  $R^7$  may be united with each other to form a divalent hydrocarbon group,  $R^4$  or  $R^5$ , and  $R^6$  or  $R^7$  10 may be bonded to each other to form a carbon ring or heterocyclic ring, and the carbon ring or heterocyclic ring may be either a monocyclic structure or a polycyclic structure.

In the ring-opened polynorbornenes according to the 20 present invention, at least 90 mol% of  $X^1$  in the general formula (I) and  $X^2$  in the general formula (II) may be

preferably ethylene groups.

The ring-opened polynorbornene may preferably have a structural unit (I) that in the general formula (I), m is 0, and n is 1.

5 The ring-opened polynorbornene may also preferably have a structural unit (I) that in the general formula (I-1), p is 0, q is 0, and at least one of  $R^{11}$  and  $R^{18}$  is another substituent group than hydrogen.

10 The ring-opened polynorbornene may further preferably have a structural unit (I) that in the general formula (I-1), p is 0, q is 0, at least one of  $R^{11}$  and  $R^{18}$  has another substituent group than hydrogen, and at least one of  $R^{12}$ ,  $R^{15}$  and  $R^{19}$  is another substituent group than hydrogen.

15 The ring-opened polynorbornene may still further preferably have a structural unit (I) that in the general formula (I-1), p is 0, q is 0, and both  $R^{11}$  and  $R^{18}$  are other substituent groups than hydrogen.

#### EFFECTS OF THE INVENTION

20 Since the ring-opened polynorbornenes according to the present invention exhibit specific wavelength dependency about birefringence and have low birefringence and high heat resistance and transparency, they are useful in fields of optical parts, electric and electronic  
25 materials, and the like. Specifically, they are useful as disks, magneto-optical disks, optical lenses (F $\Theta$  lenses, pickup lenses, lenses for laser printers, lenses for

cameras, etc.), spectacle lenses, optical films (films for display, phase difference films, polarizing films, transparent conductive films, wave plates, optical pickup films, etc.), liquid crystal orientation films, optical 5 sheets, optical fibers, light guide plates, light-diffusing plates, optical cards, optical mirrors, and sealing materials for semiconductors such as IC, LSI and LED.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Fig. 1 illustrates a  $^1\text{H-NMR}$  spectrum of Polymer (P1) according to Example 1.

Fig. 2 illustrates an IR spectrum of Polymer (P1) according to Example 1.

15 Fig. 3 illustrates a  $^1\text{H-NMR}$  spectrum of Polymer (P2) according to Example 2.

Fig. 4 illustrates an IR spectrum of Polymer (P2) according to Example 2.

Fig. 5 illustrates a  $^1\text{H-NMR}$  spectrum of Polymer (P3) according to Example 3.

20 Fig. 6 illustrates an IR spectrum of Polymer (P3) according to Example 3.

Fig. 7 illustrates a  $^1\text{H-NMR}$  spectrum of Polymer (P4) according to Example 4.

25 Fig. 8 illustrates an IR spectrum of Polymer (P4) according to Example 4.

Fig. 9 illustrates a  $^1\text{H-NMR}$  spectrum of Polymer (P5) according to Example 5.

Fig. 10 illustrates an IR spectrum of Polymer (P5) according to Example 5.

Fig. 11 illustrates a  $^1\text{H-NMR}$  spectrum of Polymer (P6) according to Example 6.

5 Fig. 12 illustrates an IR spectrum of Polymer (P6) according to Example 6.

Fig. 13 diagrammatically illustrates the wavelength dependency about birefringence in stretched films formed of polymers according to Example 1 and Comparative Example 1.

10

#### BEST MODE FOR CARRYING OUT THE INVENTION

The ring-opened polynorbornenes according to the present invention will hereinafter be described in details.

15 The ring-opened polynorbornene according to the present invention comprises the structural unit (I) represented by the general formula (I).

In the general formula (I), m and n are, independently of each other, an integer of 0 to 2, and  $\text{X}^1$  is an ethylene or vinylene group.

20  $\text{R}^1$  and  $\text{R}^2$  denote, independently of each other, a hydrogen atom or a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, preferably 1 to 10 carbon atoms. Specific examples of the hydrocarbon group include alkyl groups such as methyl, ethyl and propyl groups; cycloalkyl groups such as cyclopentyl and cyclohexyl groups; alkenyl groups such as vinyl and allyl groups; alkylidene groups such as ethylidene and

propylidene groups; aromatic groups such as a phenyl group; and groups with a part or the whole of hydrogen atoms of these groups substituted by a halogen atom such as fluorine, chlorine or bromine, a phenylsulfonyl group, or the like.

5         $R^3$  is a group represented by the above general formula (I-1) or a group represented by the above general formula (I-2).

In the general formulae (I-1) and (I-2),  $R^{11}$  to  $R^{27}$  are, independently of one another, a hydrogen atom; a 10 halogen atom; a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, preferably 1 to 20 carbon atoms, which may have a linkage containing or not containing oxygen, sulfur, nitrogen and/or silicon atom(s); or a polar group.

15        Specific examples of the halogen atom include fluorine, chlorine and bromine atoms.

Specific examples of the substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms include the same groups as those exemplified as  $R^1$  and  $R^2$  in the 20 general formula (I). These hydrocarbon groups may be directly bonded to the carbon atom of the aromatic ring or may be bonded through a linkage. In this description, the linkage is a group containing or not containing oxygen, sulfur, nitrogen and/or silicon atom(s). Specific examples 25 thereof include divalent hydrocarbon groups [for example, alkylene groups represented by  $-(CH_2)_m-$ , in which  $m$  is an integer of 1 to 10] having 1 to 10 carbon atoms, a carbonyl

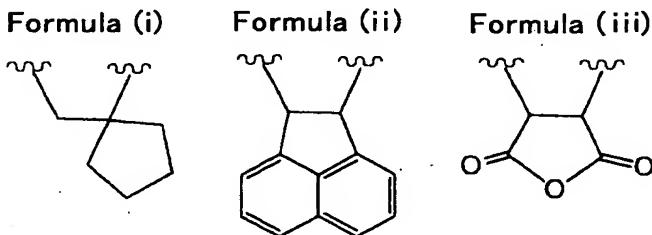
group (-CO-), a carbonyloxy group (-COO-), a sulfone group (-SO<sub>2</sub>-), an ether linkage (-O-), a thioether linkage (-S-), an imino group (-NH-), an amide linkage (-NHCO-), siloxane linkages (-Si(R<sub>2</sub>)O-, in which R is an alkyl group such as a 5 methyl or ethyl group), and combinations of 2 or more of these groups.

Examples of the polar group include hydroxyl groups, alkoxy groups having 1 to 10 carbon atoms, ester groups, alkoxycarbonyl groups, aryloxycarbonyl groups, a cyano 10 group, an amide group, an imide group, triorganosiloxy groups, triorganosilyl groups, amino groups, an acyl group, alkoxy silyl groups, a sulfonyl group and a carboxyl group. More specifically, examples of the alkoxy groups include 15 methoxy and ethoxy groups; examples of the ester groups include fatty acid ester groups such as acetate and propionate groups, and aromatic ester groups such as a benzoate group; examples of the alkoxycarbonyl groups include methoxycarbonyl and ethoxycarbonyl groups; examples of the aryloxycarbonyl groups include phenoxy carbonyl and 20 naphthoxy carbonyl, fluorenyloxy carbonyl and biphenyloxy carbonyl groups; examples of the triorganosiloxy groups include trimethylsiloxy and triethylsiloxy groups; examples of the triorganosilyl groups include trimethylsilyl and triethylsilyl groups; 25 examples of the amino groups include a primary amino group; and examples of the alkoxy silyl groups include trimethoxysilyl and triethoxysilyl groups.

In the general formula (I-1), p and q are individually 0 or a positive integer, preferably 0, 1 or 2. In the general formula (I-2), s is 0 or a positive integer, preferably 0, 1 or 2.

5 When both p and q in the general formula (I-1) are 0, R<sup>12</sup> and R<sup>15</sup>, or R<sup>19</sup> and R<sup>15</sup> may be bonded to each other to form a carbon ring or heterocyclic ring, and the carbon ring or heterocyclic ring may be either a monocyclic structure or a polycyclic structure. Specific examples of 10 such ring structures include those shown in the following formulae (i) to (iii):

[Chemical formula 4]



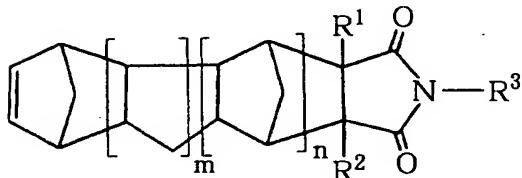
As such a structural unit (I), are preferred those, 15 in which in the general formula (I), m is 0, n is 1, both R<sup>1</sup> and R<sup>2</sup> are hydrogen atoms, and R<sup>3</sup> is a group represented by the general formula (I-1) or the general formula (I-2), in that a ring-opened polynorbornene high in heat resistance and low in water absorption property is obtained. 20 Among these, those, in which both p and q in the general formula (I-1) are 0, or s in the general formula (I-2) is 0, are more preferred, with those, in which R<sup>3</sup> is a group represented by the general formula (I-1), both p and q in the general formula (I-1) are 0, and at least one of R<sup>11</sup>

and  $R^{18}$  is another substituent group than hydrogen, being particularly preferred. Further, those, in which  $R^3$  is a group represented by the general formula (I-1), both  $p$  and  $q$  in the general formula (I-1) are 0, at least one of  $R^{11}$  5 and  $R^{18}$  has another substituent group than hydrogen, and at least one of  $R^{12}$ ,  $R^{15}$  and  $R^{19}$  is another substituent group than hydrogen, or in which both  $R^{11}$  and  $R^{18}$  are other substituent groups than hydrogen, being particularly preferred.

10 Such a structural unit (I) is obtained by subjecting a norbornene monomer (hereinafter referred to as "Specific Monomer (I)") represented by the following general formula (Im) to ring-opening polymerization.

[Chemical formula 5]

15 General formula (Im)



As such Specific Monomer (I), may be used an imide compound obtained by, for example, a reaction of a norbornenic acid anhydride such as 4-oxa-tricyclo-20 [5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione or 6-oxa-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione with an aromatic amine. Specific examples thereof include  
 (1) 4-phenyl-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,  
 (2) 6-phenyl-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-

12-ene-5,7-dione,

(3) 4-(2-methylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(4) 6-(2-methylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.

5 0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(5) 4-(2,6-dimethylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(6) 6-(2,6-dimethylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

10 (7) 4-(2,6-diethylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(8) 6-(2,6-diethylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

15 (9) 4-(2,4-dimethylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(10) 6-(2,4-dimethylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(11) 4-(4-chloro-2-methylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-dec-8-ene-3,5-dione,

20 (12) 6-(4-chloro-2-methylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(13) 4-(4-chlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(14) 6-(4-chlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.

25 0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(15) 4-(2-chlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(16) 6-(2-chlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(17) 4-(3-chlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-  
3,5-dione,

5 (18) 6-(3-chlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(19) 4-(2,5-dichlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-  
ene-3,5-dione,

(20) 6-(2,5-dichlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
10 0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(21) 4-(2,4-dichlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-  
ene-3,5-dione,

(22) 6-(2,4-dichlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

15 (23) 4-(2,6-dichlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-  
ene-3,5-dione,

(24) 6-(2,6-dichlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(25) 4-(2,4,5-trichlorophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-  
20 dec-8-ene-3,5-dione,

(26) 6-(2,4,5-trichlorophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.  
0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(27) 4-(4-bromophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-  
3,5-dione,

25 (28) 6-(4-bromophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(29) 4-(4-bromo-2,6-dimethylphenyl)-4-aza-tricyclo[5.2.1.

$0^{2,6}]$  dec-8-ene-3,5-dione,

(30) 6-(4-bromo-2,6-dimethylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(31) 4-(4-ethoxycarbonylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-5 dec-8-ene-3,5-dione,

(32) 6-(4-ethoxycarbonylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(33) 4-(4-ethoxycarbonyl-2-methylphenyl)-4-aza-tricyclo-[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

10 (34) 6-(4-ethoxycarbonyl-2-methylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(35) 4-(5-ethoxycarbonyl-2-methylphenyl)-4-aza-tricyclo-[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(36) 6-(5-ethoxycarbonyl-2-methylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

15 (37) 4-(2-methoxy-5-methoxycarbonylphenyl)-4-aza-tricyclo-[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(38) 6-(2-methoxy-5-methoxycarbonylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

20 (39) 4-(2-chloro-5-dodecyloxycarbonylphenyl)-4-aza-tricyclo-[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(40) 6-(2-chloro-5-dodecyloxycarbonylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(41) 4-(2-ethoxycarbonylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-25 dec-8-ene-3,5-dione,

(42) 6-(2-ethoxycarbonylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(43) 4-(2-ethoxycarbonyl-4,5-dimethoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(44) 6-(2-ethoxycarbonyl-4,5-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

5 (45) 4-(2-methoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(46) 6-(2-methoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(47) 4-(4-methoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

10 (48) 6-(4-methoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(49) 4-(2,4-dimethoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

15 (50) 6-(2,4-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(51) 4-(3,5-dimethoxycarbonylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(52) 6-(3,5-dimethoxycarbonylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

20 (53) 4-(4-chloro-2,5-dimethoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(54) 6-(4-chloro-2,5-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

25 (55) 4-(5-chloro-2,4-dimethoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

(56) 6-(5-chloro-2,4-dimethoxyphenyl)-6-aza-pentacyclo-

[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,  
(57) 4-(2,5-diethoxyphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-  
ene-3,5-dione,  
(58) 6-(2,5-diethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.  
5 0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,  
(59) 4-(3-methoxycarbonyl-4-methoxyphenyl)-4-aza-  
tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,  
(60) 6-(3-methoxycarbonyl-4-methoxyphenyl)-6-aza-  
pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,  
10 (61) 4-(2-methyl-4-nitrophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-  
dec-8-ene-3,5-dione,  
(62) 6-(2-methyl-4-nitrophenyl)-6-aza-pentacyclo-  
[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,  
(63) 4-(4-nitrophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-  
15 3,5-dione,  
(64) 6-(4-nitrophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,  
(65) 4-(4-cyanophenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-  
3,5-dione,  
20 (66) 6-(4-cyanophenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,  
(67) 4-(4-biphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-  
dione,  
(68) 6-(4-biphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]-  
25 pentadec-12-ene-5,7-dione,  
(69) 4-(2-biphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-  
dione,

(70) 6-(2-biphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]-pentadec-12-ene-5,7-dione,

(71) 4-(3-biphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene-3,5-dione,

5 (72) 6-(3-biphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]-pentadec-12-ene-5,7-dione,

(73) 4-(2-methoxydibenzofuranyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-dec-8-ene-3,5-dione,

10 (74) 6-(2-methoxydibenzofuranyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione,

(75) 4-(9-fluorenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-dec-8-ene-3,5-dione,

15 (76) 6-(9-fluorenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]-pentadec-12-ene-5,7-dione,

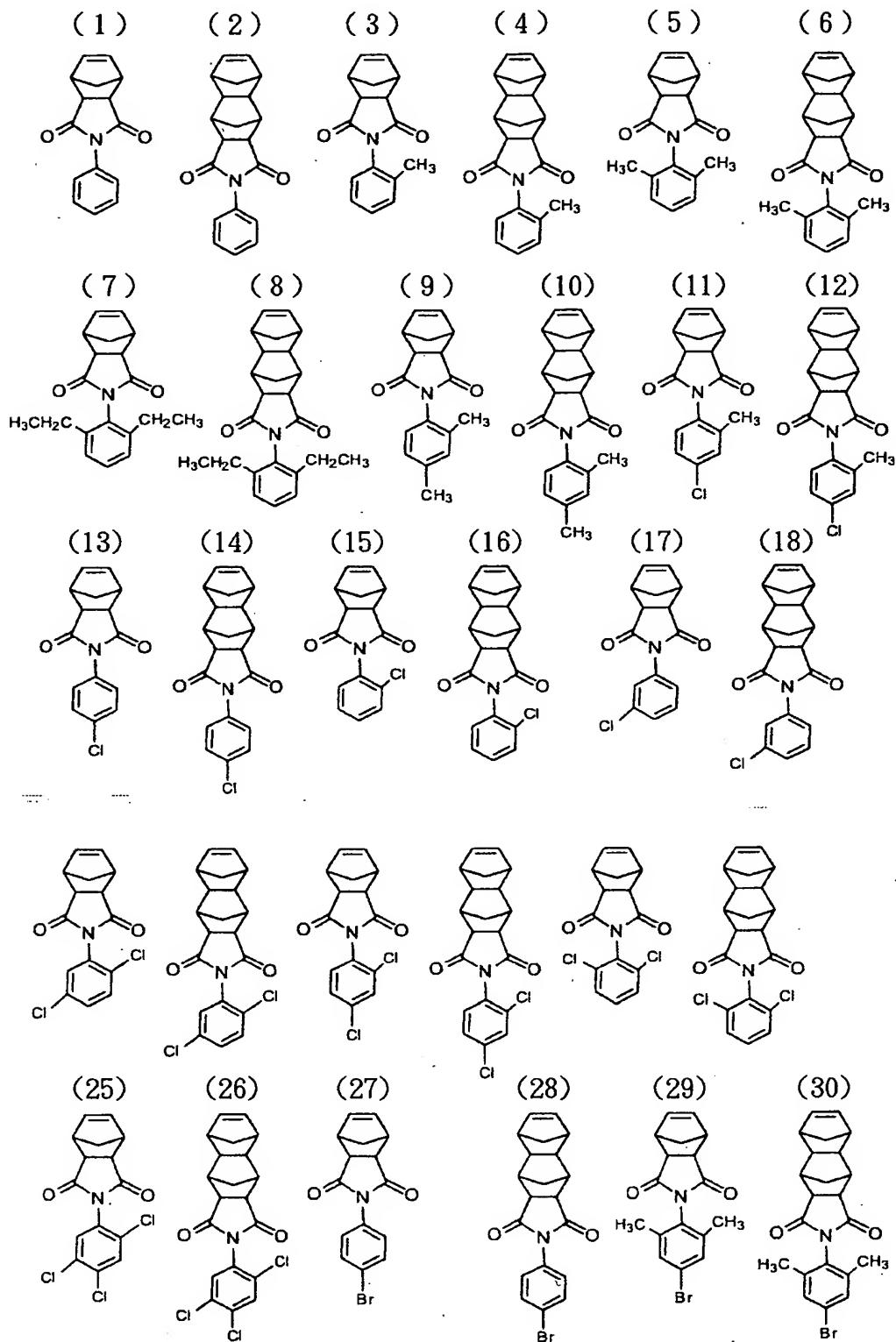
(77) 2-methyl-4-(2-methylphenyl)-4-aza-tricyclo[5.2.1.0<sup>2,6</sup>]-dec-8-ene-3,5-dione, and

(78) 4-methyl-6-(2-methylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione.

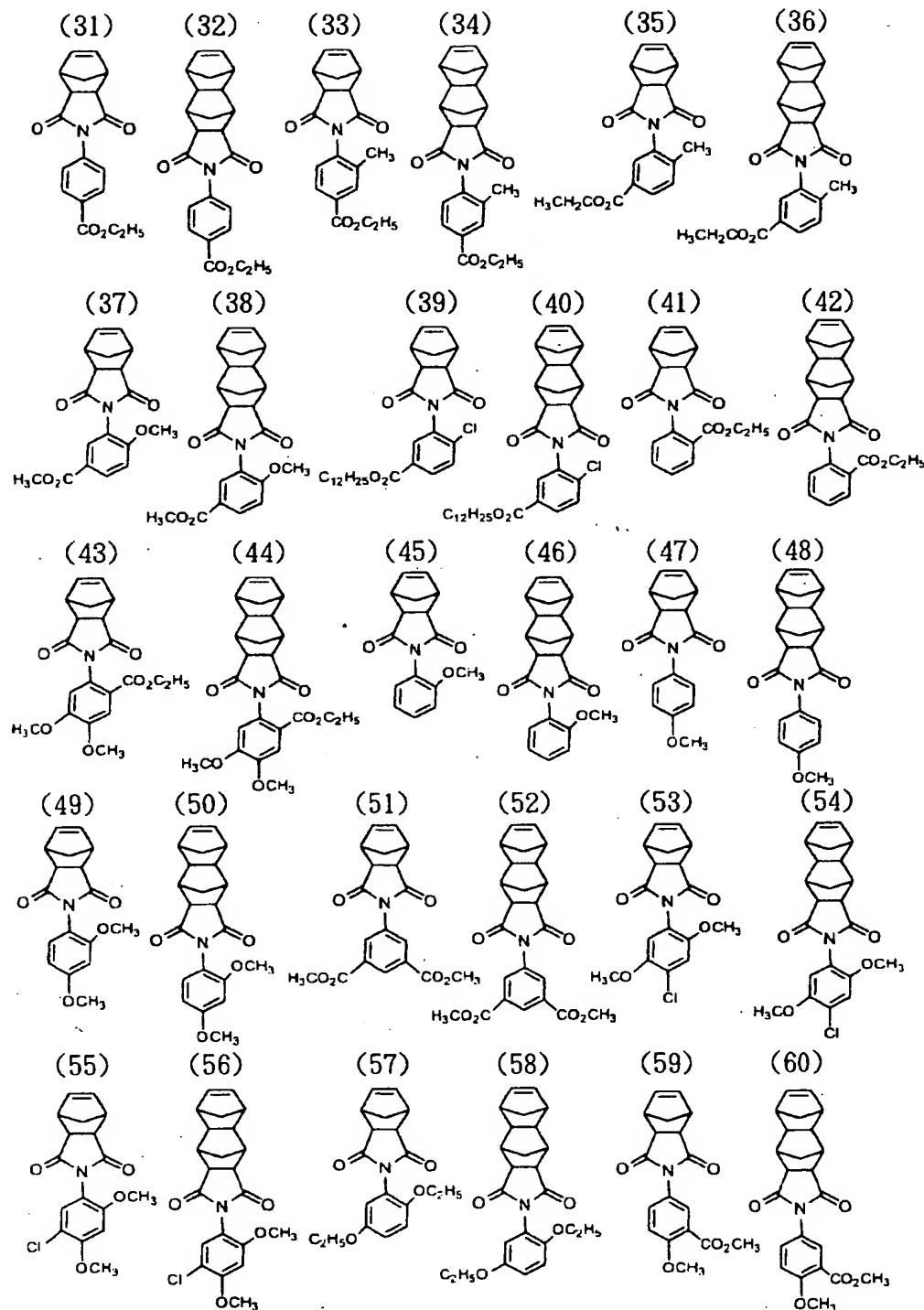
These compound may be used as Specific Monomer (I) either  
20 singly or in any combination thereof.

The structural formulae of the above-mentioned  
compounds (1) to (78) are shown below.

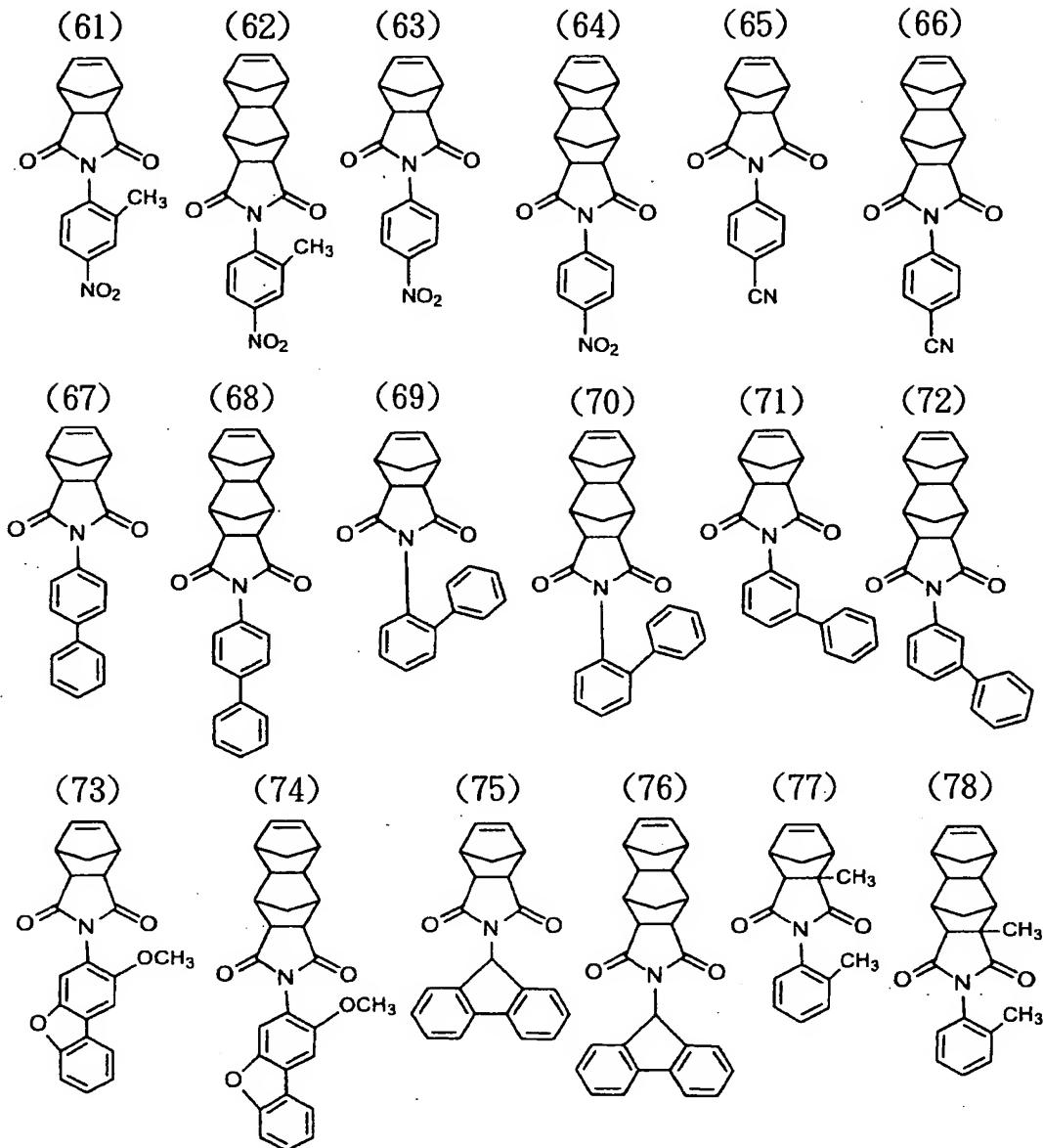
[Chemical formula 6]



[Chemical formula 7]



[Chemical formula 8]



The ring-opened polynorbornenes according to the  
 5 present invention may have a structural unit (II)  
 represented by the above general formula (II) in addition  
 to the structural unit (I).

In the general formula (II), t and u are,

independently of each other, 0 or a positive integer, and preferably t is 0 or 1, and u is an integer of 0 to 3.  $x^2$  is an ethylene or vinylene group.

$R^4$  to  $R^7$  are, independently of one another, a hydrogen atom; a halogen atom; a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, which may have a linkage containing or not containing oxygen, sulfur, nitrogen and/or silicon atom(s); or a polar group, with the proviso that  $R^4$  and  $R^5$ , or  $R^6$  and  $R^7$  may be united with each other to form a divalent hydrocarbon group, or  $R^4$  or  $R^5$ , and  $R^6$  or  $R^7$  may be bonded to each other to form a carbon ring or heterocyclic ring, and the carbon ring or heterocyclic ring may be either a monocyclic structure or a polycyclic structure. Specific examples of these atoms or groups include the same atoms or groups as those exemplified as  $R^1$  and  $R^2$  in the general formula (I) and  $R^{11}$  to  $R^{27}$  in the general formula (I-1) and the general formula (I-2).

As such a structural unit (II), are preferred those, in which in the general formula (II), at least one of  $R^4$  to  $R^7$  is a carboxylic acid ester group represented by -  $(CH_2)_kCOOR^{29}$ , in which  $R^{29}$  is a hydrocarbon group having 1 to 20 carbon atoms, and k is an integer of 0 to 10, in that a copolymer good in balance among heat resistance, solubility and adhesion property or adhesive property to other materials, etc. is obtained.

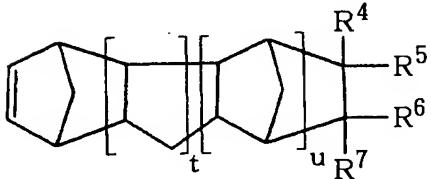
Specific examples of the hydrocarbon group having 1

to 20 carbon atoms represented by  $R^{29}$  include alkyl groups such as methyl, ethyl and propyl groups, aryl groups such as a phenyl group, and aralkyl groups such as a benzyl group. Among these, methyl, ethyl and phenyl groups are 5 preferred, with a methyl group being more preferred.

Such a structural unit (II) is obtained by subjecting a norbornene monomer (hereinafter referred to as "Specific Monomer (II)") represented by the following general formula (IIm) to ring-opening copolymerization with Specific 10 Monomer (I).

[Chemical formula 9]

General formula (IIm)



wherein in the general formula (IIm), t and u are, 15 independently of each other, 0 or a positive integer,  $R^4$  to  $R^7$  denote, independently of one another, a hydrogen atom; a halogen atom; a substituted or unsubstituted hydrocarbon group having 1 to 30 carbon atoms, which may have a linkage containing or not containing oxygen, sulfur, nitrogen 20 and/or silicon atom(s); or a polar group, with the proviso that  $R^4$  and  $R^5$ , or  $R^6$  and  $R^7$  may be united with each other to form a divalent hydrocarbon group, or  $R^4$  and  $R^5$ , or  $R^6$  and  $R^7$  may be bonded to each other to form a carbon ring or heterocyclic ring, and the carbon ring or heterocyclic ring

may be either a monocyclic structure or a polycyclic structure.

Specific examples of such Specific Monomer (II) include

- 5 (79) bicyclo[2.2.1]hepto-2-ene,
- (80) tricyclo[5.2.1.0<sup>2,6</sup>]dec-8-ene,
- (81) tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,
- (82) pentacyclo[9.2.1.1<sup>4,7</sup>.0<sup>2,10</sup>.0<sup>3,8</sup>]pentadec-5-ene,
- (83) heptacyclo[13.2.1.1<sup>3,13</sup>.1<sup>6,9</sup>.0<sup>2,14</sup>.0<sup>4,12</sup>.0<sup>5,10</sup>]icos-7-ene,
- 10 (84) 5-methylbicyclo[2.2.1]hepto-2-ene,
- (85) 5-ethylbicyclo[2.2.1]hepto-2-ene,
- (86) 5-n-hexylbicyclo[2.2.1]hepto-2-ene,
- (87) 5-isopropylbicyclo[2.2.1]hepto-2-ene,
- (88) 5-n-octylbicyclo[2.2.1]hepto-2-ene,
- 15 (89) 5-n-decylbicyclo[2.2.1]hepto-2-ene,
- (90) 5-cyclohexylbicyclo[2.2.1]hepto-2-ene,
- (91) 5-(3-cyclohexenyl)bicyclo[2.2.1]hepto-2-ene,
- (92) 5-ethylidenebicyclo[2.2.1]hepto-2-ene,
- (93) 8-ethylidenetetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,
- 20 (94) 8-ethyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,
- (95) 5-cyanobicyclo[2.2.1]hepto-2-ene,
- (96) 5-cyano-5-methylbicyclo[2.2.1]hepto-2-ene,
- (97) 5-methoxycarbonylbicyclo[2.2.1]hepto-2-ene,
- (98) 5-methyl-5-methoxycarbonylbicyclo[2.2.1]hepto-2-ene,
- 25 (99) 5-ethoxycarbonylbicyclo[2.2.1]hepto-2-ene,
- (100) 8-cyanotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,
- (101) 8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-

ene,

(102) 8-ethoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(103) 8-isopropoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

5 (104) 8-n-propoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(105) 8-n-butoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(106) 8-methyl-8-cyanotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

10 (107) 8-methyl-8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-dodec-3-ene,

(108) 8-methyl-8-ethoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-dodec-3-ene,

15 (109) 8-methyl-8-n-propoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(110) 8-methyl-8-isopropoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(111) 8-methyl-8-n-butoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

20 (112) 8-phenoxy carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-dodec-3-ene,

(113) 8-(1-naphthoxy) carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-dodec-3-ene,

(114) 8-(2-naphthoxy) carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-dodec-3-ene,

(115) 8-(4-phenylphenoxy) carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(116) 8-methyl-8-phenoxy carbonyl tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(117) 8-methyl-8-(1-naphthoxy) carbonyl tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

5 (118) 8-methyl-8-(2-naphthoxy) carbonyl tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(119) 8-methyl-8-(4-phenylphenoxy) carbonyl tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(120) 5-phenylbicyclo[2.2.1]hepto-2-ene,

10 (121) 5-(1-naphthyl)bicyclo[2.2.1]hepto-2-ene,

(122) 5-(2-naphthyl)bicyclo[2.2.1]hepto-2-ene,

(123) 5-(4-biphenyl)bicyclo[2.2.1]hepto-2-ene,

(124) 5-(2-naphthyl)-5-methylbicyclo[2.2.1]hepto-2-ene,

(125) 5-(4-biphenyl)-5-methylbicyclo[2.2.1]hepto-2-ene,

15 (126) 8-phenyl tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]3-dodecene,

(127) 5-hydroxybicyclo[2.2.1]hepto-2-ene,

(128) 5-methoxybicyclo[2.2.1]hepto-2-ene,

(129) 5-hydroxymethylbicyclo[2.2.1]hepto-2-ene,

(130) 5-aminomethylbicyclo[2.2.1]hepto-2-ene,

20 (131) 5-chloromethylbicyclo[2.2.1]hepto-2-ene,

(132) 5-trimethoxysilyl bicyclo[2.2.1]hepto-2-ene,

(133) 5-triethoxysilyl bicyclo[2.2.1]hepto-2-ene,

(134) 5-tri-n-propoxysilyl bicyclo[2.2.1]hepto-2-ene,

(135) 5-tri-n-butoxysilyl bicyclo[2.2.1]hepto-2-ene,

25 (136) 5-fluorobicyclo[2.2.1]hepto-2-ene,

(137) 5-fluoromethylbicyclo[2.2.1]hepto-2-ene,

(138) 5-trifluoromethylbicyclo[2.2.1]hepto-2-ene,

(139) 5-pentafluoroethylbicyclo[2.2.1]hepto-2-ene,  
(140) 5,5-difluorobicyclo[2.2.1]hepto-2-ene,  
(141) 5,6-difluorobicyclo[2.2.1]hepto-2-ene,  
(142) 5,5-bis(trifluoromethyl)bicyclo[2.2.1]hepto-2-ene,  
5 (143) 5,6-bis(trifluoromethyl)bicyclo[2.2.1]hepto-2-ene,  
(144) 5-methyl-5-trifluoromethylbicyclo[2.2.1]hepto-2-ene,  
(145) 5,5,6-trifluorobicyclo[2.2.1]hepto-2-ene,  
(146) 5,5,6-tris(fluoromethyl)bicyclo[2.2.1]hepto-2-ene,  
(147) 5,5,6,6-tetrafluorobicyclo[2.2.1]hepto-2-ene,  
10 (148) 5,5,6,6-tetrakis(trifluoromethyl)bicyclo[2.2.1]hepto-  
2-ene,  
(149) 5,5-difluoro-6,6-bis(trifluoromethyl)bicyclo[2.2.1]-  
hepto-2-ene,  
(150) 5-fluoro-6-pentafluoroethylbicyclo[2.2.1]-hepto-2-ene,  
15 (151) 5-chloro-5,6,6-trifluorobicyclo[2.2.1]hepto-2-ene,  
(152) 5,5,6-trifluoro-6-trifluoromethoxybicyclo[2.2.1]-  
hepto-2-ene,  
(153) 8-fluorotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,  
(154) 8-fluoromethyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,  
20 (155) 8-trifluoromethyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-  
ene,  
(156) 8-pentafluoroethyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-  
ene,  
(157) 8,8-difluorotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,  
25 (158) 8,9-difluorotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,  
(159) 8,8-bis(trifluoromethyl)tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-  
dodec-3-ene,

(160) 8,9-bis(trifluoromethyl)tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]-dodec-3-ene,

(161) 8-methyl-8-trifluoromethyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

5 (162) 8,8,9-trifluorotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(163) 8,8,9-tris(trifluoromethyl)tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(164) 8,8,9,9-tetrafluorotetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

10 (165) 8,8,9,9-tetrakis(trifluoromethyl)tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

(166) 8,8-difluoro-9,9-bis(trifluoromethyl)tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene,

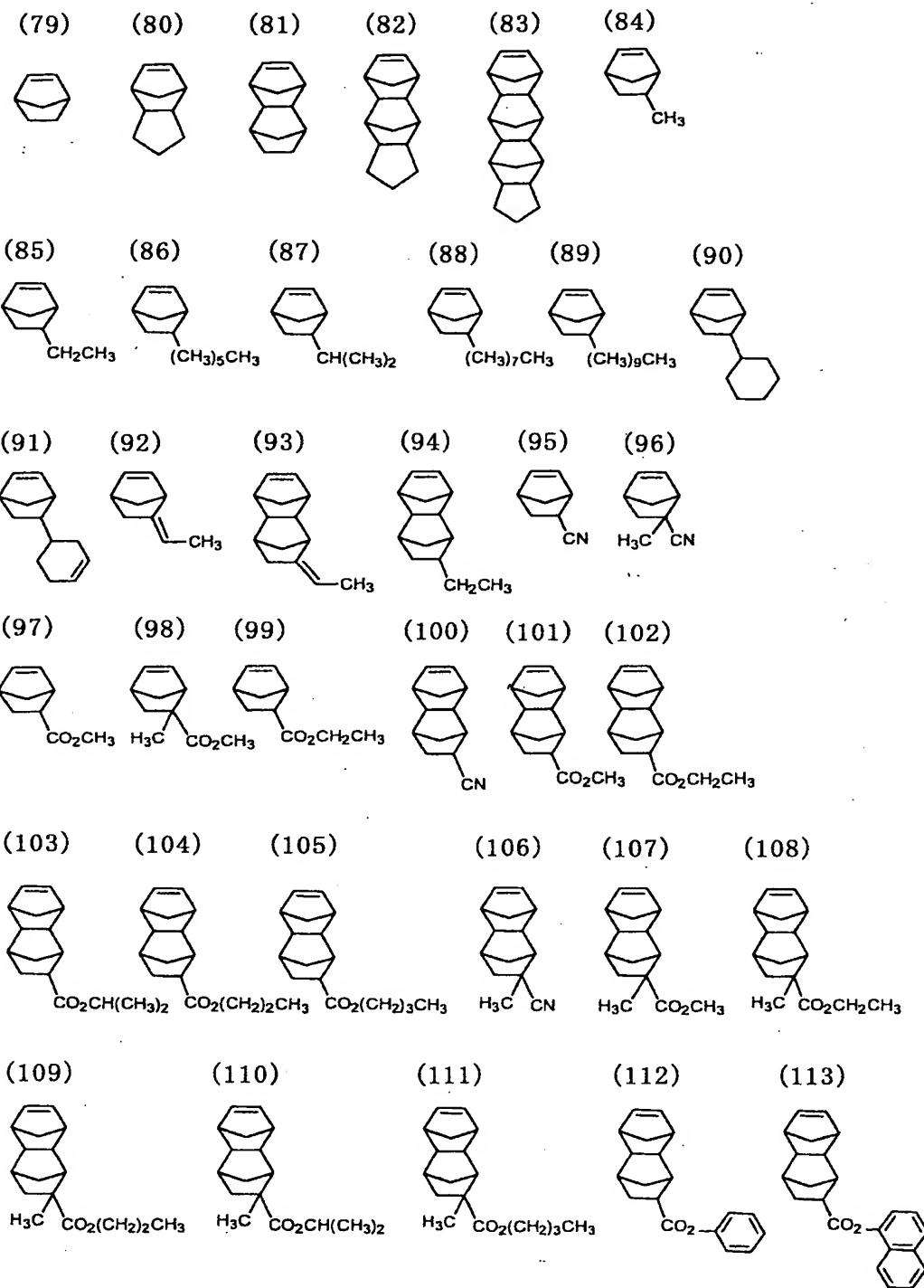
(167) 8,9-difluoro-8,9-bis(trifluoromethyl)tetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene, and

15 (168) 8,8,9-trifluoro-9-trifluoromethoxytetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene.

These compound may be used as Specific Monomer (II) either singly or in any combination thereof.

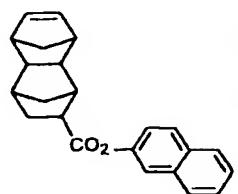
20 The structural formulae of the above-mentioned compounds (79) to (168) are shown below.

[Chemical formula 10]

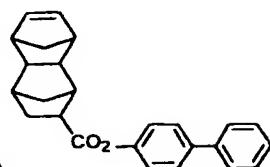


[Chemical formula 11]

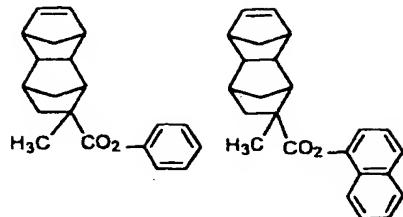
(114)



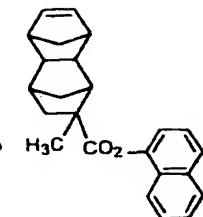
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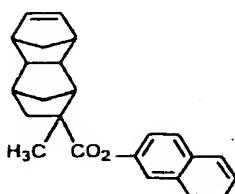
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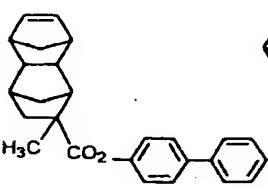
(117)



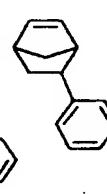
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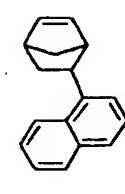
(119)



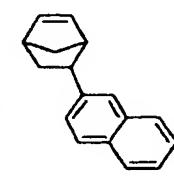
(120)



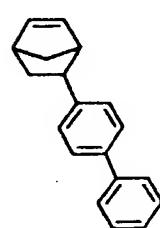
(121)



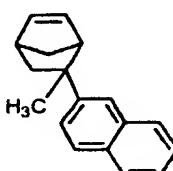
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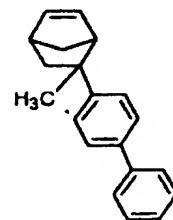
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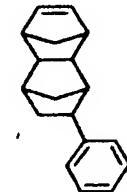
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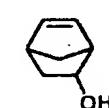
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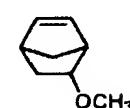
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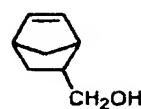
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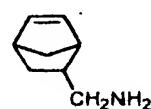
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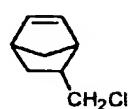
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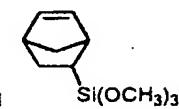
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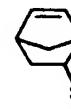
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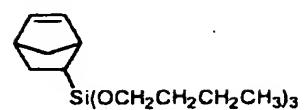
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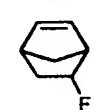
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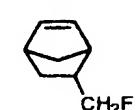
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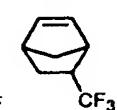
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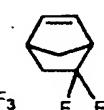
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(141)



[Chemical formula 12]

(142)



(143)



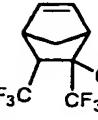
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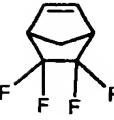
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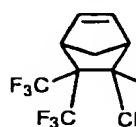
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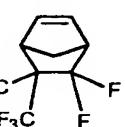
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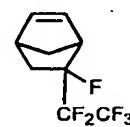
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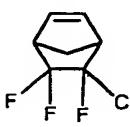
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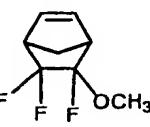
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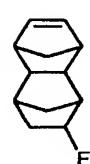
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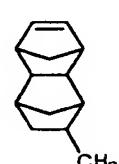
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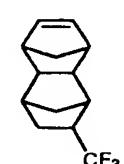
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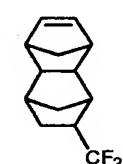
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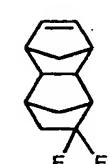
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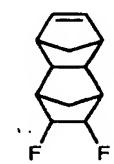
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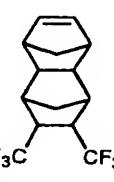
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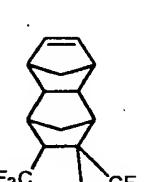
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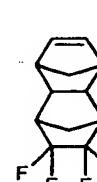
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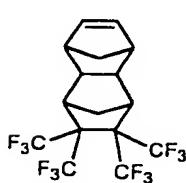
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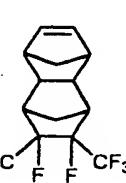
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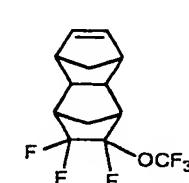
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Among these, 8-methyl-8-methoxycarbonyltetracyclo-

5 [4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene is particularly preferred in

that its preparation process is easy.

When the structural unit (II) is contained in the ring-opened polynorbornene according to the present invention, the proportion of the structural unit (II) is 5 preferably at most 98 mol% based on the whole structural unit.

A ratio of the structural unit (I) to the structural unit (II) is generally 100:0 to 2:98, preferably 100:0 to 5:95, more preferably 100:0 to 10:90 in terms of a molar 10 ratio.

If the proportion of the structural unit (II) is too high, the specific wavelength dependency about birefringence on that birefringence becomes higher as the wavelength of transmitted light becomes longer, and low 15 birefringence may not be achieved in some cases.

In the ring-opened polynorbornenes according to the present invention, the total proportion of the structural unit (I) that  $X^1$  in the general formula (I) is an ethylene group and the structural unit (II) that  $X^2$  in the general 20 formula (II) is an ethylene group is preferably at least 90 mol%, more preferably at least 95 mol%, still more preferably at least 98 mol% of the structural unit (I) and the structural unit (II). If this proportion is too low, the heat resistance of the resulting ring-opened 25 polynorbornene may become low in some cases.

The ring-opened polynorbornenes according to the present invention may have any other structural unit

(hereinafter referred to as "further structural unit") than the structural unit (I) and the structural unit (II).

As monomers for obtaining such further structural unit, may be used cycloolefins such as cyclobutane, 5 cyclopentene, cyclooctene and cyclododecene, and non-conjugated cyclic polyenes such as 1,4-cyclooctadiene, dicyclopentadiene and cyclododecatriene.

In the present invention, ring-opening polymerization of Specific Monomer (I), Specific Monomer (II) and the 10 other monomer(s) may be conducted in the presence of polybutadiene, polyisoprene, a styrene-butadiene polymer, an ethylene-non-conjugated diene polymer, an unhydrogenated product of a ring-opened (co)polymer of a norbornene monomer, or the like.

15 When the further structural unit is contained in the ring-opened polynorbornene according to the present invention, the proportion of the structural unit (I) is preferably at least 2 mol%, more preferably at least 5 mol%, still more preferably at least 10 mol% based on the whole 20 structural unit.

If the proportion of the structural unit (I) is too low, the specific wavelength dependency about birefringence on that birefringence becomes higher as the wavelength of transmitted light becomes longer, and low birefringence may 25 not be achieved in some cases.

The ring-opened polynorbornene according to the present invention has a logarithmic viscosity ( $\eta_{inh}$ ) of

generally 0.2 to 5.0, preferably 0.3 to 4.0, more preferably 0.35 to 2.0 as measured by a Ubbelohde viscometer.

Its number average molecular weight (Mn) in terms of 5 polystyrene as measured by gel permeation chromatography (GPC; tetrahydrofuran solvent) is generally 1,000 to 500,000, preferably 2,000 to 300,000, more preferably 5,000 to 300,000, and its weight average molecular weight (Mw) as measured in the same manner as described above is generally 10 5,000 to 2,000,000, preferably 10,000 to 1,000,000, more preferably 15,000 to 500,000.

If the logarithmic viscosity ( $\eta_{inh}$ ) is lower than 0.2, the number average molecular weight (Mn) is lower than 1,000, or the weight average molecular weight (Mw) is lower 15 than 5,000, the strength of such a ring-opened polynorbornene may become markedly low in some cases. On the other hand, if the logarithmic viscosity ( $\eta_{inh}$ ) exceeds 5.0, the number average molecular weight (Mn) exceeds 500,000, or the weight average molecular weight (Mw) 20 exceeds 2,000,000, the melt viscosity or solution viscosity of such a ring-opened polynorbornene may become too high in some cases, resulting in difficulty in providing a desired molded or formed product.

Publicly known various additives may be added to the 25 ring-opened polynorbornenes according to the present invention.

Specifically, a phenolic or hydroquinone antioxidant

such as triethylene glycol-bis[3-(3-t-butyl-5-methyl-4-hydroxyphenyl) propionate], 1,6-hexanediol-bis[3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate], 2,4-bis(n-octylthio)-6-(4-hydroxy-3,5-di-t-butylnilino)-1,3,5-triazine,

5 pentaerythrityl-tetrakis[3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate], 2,2-thio-diethylenebis[3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate], octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate, N,N'-hexamethylenebis(3,5-di-t-butyl-4-hydroxy)-hydrocinnamamide, 3,5-t-butyl-4-hydroxy-4-

10 benzylphosphonate-diethyl ester or 1,3,5-trimethyl-2,4,6-tris(3',5'-di-t-butyl-4-hydroxybenzyl)benzene, or a phosphorus antioxidant such as tris(4-methoxy-3,5-diphenyl)phosphite, tris(nonylphenyl)phosphite or tris(2,4-di-t-butylphenyl)phosphite may be used. The oxidation

15 stability of the resulting ring-opened polynorbornene can be improved by adding one or more of these antioxidants.

An ultraviolet absorbent such as 2,4-dihydroxybenzophenone, 2-hydroxy-4-methoxybenzophenone or 2,2-methylenebis[4-(1,1,3,3-tetramethylbutyl)-6-[(2H-

20 benzotriazol-2-yl)phenol]], or of the hindered amine type or benzoate type may also be used. The light resistance of the resulting ring-opened polynorbornene can be improved by adding one or more of these ultraviolet absorbents.

Additives such as a lubricant may also be added for

25 the purpose of improving processability.

The ring-opened polynorbornene according to the present invention can be prepared by subjecting Specific

Monomer (I) to ring-opening polymerization or subjecting Specific Monomer (I) to ring-opening copolymerization with Specific Monomer (II) and the other monomer(s) used as needed, or subjecting these monomers to ring-opening 5 (co)polymerization and then further hydrogenating the resultant (co)polymer.

[Ring-opening polymerization catalyst]

As ring-opening polymerization catalysts used in the present invention, are used catalysts described in Olefin 10 Metathesis and Metathesis Polymerization (K. J. IVIN, J. C. MOL, Academic Press, 1997), for example, the following metathesis polymerization catalysts. More specifically, those are catalysts composed of a combination of (a) at least one selected from compounds of W, Mo, Re, V and Ti 15 and (b) at least one selected from compounds of Li, Na, K, Mg, Ca, Zn, Cd, Hg, B, Al, Si, Sn, Pb and the like, which have at least one element-carbon bond, or at least one element-hydrogen bond. In order to enhance activity of the catalyst in this case, an additive (c), which will be 20 described subsequently, may also be added. Examples of other catalysts include (d) metathesis catalysts composed of a carbene complex of a metal of Group 4 to Group 8 of the periodic table or metallacyclo butene complex using no promoter.

25 As typical examples of the compounds of W, Mo, Re, V and Ti, which are suitable for use as the component (a), may be mentioned the compounds described in Japanese Patent

Application Laid-Open No. 240517/1989, such as  $WCl_6$ ,  $MoCl_5$ ,  $ReOCl_3$ ,  $VOCl_3$  and  $TiCl_4$ .

As specific examples of the compounds used as the component (b), may be mentioned the compounds described in 5 Japanese Patent Application Laid-Open No. 240517/1989, such as  $n-C_4H_9Li$ ,  $(C_2H_5)_3Al$ ,  $(C_2H_5)_2AlCl$ ,  $(C_2H_5)_{1.5}AlCl_{1.5}$ ,  $(C_2H_5)AlCl_2$ , methyl alumoxane and  $LiH$ .

As typical examples of the additive, which is the component (c), may be suitably used alcohols, aldehydes, 10 ketones and amines. Further, the compounds described in Japanese Patent Application Laid-Open No. 240517/1989 may also be used.

Typical examples of the component (d) include  $W(=N-2,6-C_6H_3^iPr_2)(=CH^tBu)(O^tBu)_2$ ,  $Mo(=N-2,6-C_6H_3^iPr_2)(=CH^tBu)(O^tBu)_2$ ,  $Ru(=CHCH=CPh_2)(PPh_3)_2Cl_2$  and 15  $Ru(=CHPh)(PC_6H_{11})_2Cl$ .

The amount of the metathesis catalyst used is within a range that a proportion of the component (a) to the total of Specific Monomer (I) and Specific Monomer (II) amounts 20 to 1:500 to 1:500,000 in terms of a molar ratio, preferably 1:1,000 to 1:100,000.

A proportion of the component (a) to the component (b) is within a range of 1:1 to 1:100 in terms of a metal atom ratio of "the component (a) to the component (b)", 25 preferably 1:2 to 1:50. A proportion of the component (a) to the component (c) is within a range of 0.005:1 to 15:1 in terms of a molar ratio of "the component (c) to the

component (a)", preferably 0.05:1 to 10:1. The amount of the catalyst (d) used is within a range that a proportion of the component (d) to the total of Specific Monomer (I) and Specific Monomer (II) amounts to 1:30 to 1:100,000 in 5 terms of a molar ratio, preferably 1:50 to 1:50,000.

[Molecular weight modifier]

The molecular weight of the ring-opened polymer may also be controlled by a polymerization temperature, the kind of a catalyst used and the kind of a solvent used. In 10 the present invention, however, the molecular weight is preferably controlled by causing a molecular weight modifier to coexist in the reaction system. As examples of molecular weight modifiers suitable for use herein, may be mentioned  $\alpha$ -olefins such as ethylene, propene, 1-butene, 15 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene and 1-decene, and styrene. Among these, 1-butene and 1-hexene are particularly preferred. These molecular weight modifiers may be used either singly or in any combination thereof.

20 The amount of the molecular weight modifier used is 0.005 to 1.0 mol, preferably 0.02 to 0.5 mol per mol in total of Specific Monomer (I) and Specific Monomer (II) used in the ring-opening (co)polymerization reaction.

[Ring-opening polymerization solvent]

25 As specific examples of a solvent (solvent for dissolving the monomers, metathesis catalyst and molecular weight modifier) used in the ring-opening polymerization

reaction, may be mentioned alkanes such as pentane, hexane, heptane, octane, nonane and decane; cycloalkanes such as cyclohexane, cyclopentane, cyclooctane, decalin and norbornane; aromatic hydrocarbons such as benzene, toluene, 5 xylene, ethylbenzene and cumene; halogenated alkanes such as chlorobutane, bromohexane, methylene chloride, dichloroethane, hexamethylene dibromide, chlorobenzene, chloroform and tetrachloroethylene; aryl compounds; saturated carboxylic acid esters such as ethyl acetate, n-10 butyl acetate, isobutyl acetate, methyl propionate and dimethoxyethane; and ethers such as dibutyl ether, tetrahydrofuran and dimethoxyethane. These solvents may be used either singly or in any combination thereof. Among these, the aromatic hydrocarbons are preferred.

15 The amount of the solvent used is such that a weight ratio of "solvent to monomer(s)" amounts to 1:1 to 30:1, preferably 1:1 to 20:1.

The ring-opened polynorbornene obtained by the above-described ring-opening polymerization has the structural 20 unit (I) and structural unit (II), in which both  $X^1$  in the general formula (I) and  $X^2$  in the general formula (II) are vinylene groups. Such a polynorbornene may be used in various application fields as it is. From the viewpoint of heat stability, however, a part or the whole of the 25 vinylene groups in the ring-opened polymer are preferably hydrogenated into ethylene groups to provide a hydrogenated product. In such a hydrogenated product, the aromatic

rings located at side chains based on Specific Monomers (I) and (II) are preferably substantially not hydrogenated.

The hydrogenation rate of the vinylene groups is preferably at least 90%, more preferably at least 95%, 5 still more preferably at least 98%. Coloration or deterioration by heat is more inhibited as the hydrogenation rate is higher. It is hence preferable that the hydrogenation rate be higher.

It is necessary to conduct the hydrogenation reaction 10 under conditions that the aromatic rings located at side chains based on Specific Monomers (I) and (II) are substantially not hydrogenated. In general, the hydrogenation reaction is conducted by adding a hydrogenation catalyst to a solution of the ring-opened 15 polymer and causing hydrogen gas of normal pressure to 300 atm, preferably 3 to 200 atm to act on the solution at 0 to 200°C, preferably 20 to 180°C.

As the hydrogenation catalyst, may be used that used 20 in an ordinary hydrogenation reaction of an olefinic compound. As such a hydrogenation catalyst, may be used either a heterogeneous catalyst or a homogenous catalyst. As specific examples of the heterogeneous catalyst, may be mentioned solid catalysts with a noble metal catalytic substance such as palladium, platinum, nickel, rhodium or 25 ruthenium carried on a carrier such as carbon, silica, alumina or titania. As specific examples of the homogenous catalyst, may be mentioned nickel naphthenate/

triethylaluminum, nickel acetylacetonate/triethylaluminum,  
cobalt octanoate/n-butyllithium, titanocene dichloride/  
diethylaluminum monochloride, rhodium acetate,  
chlorotris(triphenylphosphine)rhodium, dichlorotris-  
5 (triphenylphosphine)ruthenium, chlorohydrocarbonyltris-  
(triphenylphosphine)ruthenium and dichlorocarbonyltris-  
(triphenylphosphine)ruthenium. The form of the catalyst  
may be either powder or particles.

In order to substantially prevent the aromatic rings  
10 located at the side chains based on Specific Monomers (I)  
and (II) from being hydrogenated, it is necessary to  
control the amount of these hydrogenation catalysts.  
However, the catalyst is generally used in a proportion  
that a weight ratio of "the ring-opened polymer to "the  
15 hydrogenation catalyst" amounts to  $1:(1 \times 10^{-6})$  to 1:2.

Since the ring-opened polynorbornenes according to  
the present invention exhibit specific wavelength  
dependency about birefringence and have low birefringence  
and high heat resistance and transparency, they are useful  
20 in fields of optical parts, electric and electronic  
materials, etc. Specifically, they are useful as disks,  
magneto-optical, optical lenses (FO lenses, pickup lenses,  
lenses for laser printers, lenses for cameras, etc.),  
spectacle lenses, optical films (films for display, phase  
25 difference films, polarizing films, transparent conductive  
films, wave plates, optical pickup films, etc.), liquid  
crystal orientation films, optical sheets, optical fibers,

light guide plates, light-diffusing plates, optical cards, optical mirrors, and sealing materials for semiconductors such as IC, LSI and LED.

[EXAMPLES]

5 The ring-opened polynorbornene of the present invention will hereinafter be described specifically by the following Examples. However, the present invention is not limited to these examples.

In the following Examples and Comparative Example,  
10 the glass transition temperature (Tg), number average molecular weight (Mn), weight average molecular weight (Mw) and molecular weight distribution (Mw/Mn) were measured or determined in accordance with the following respective methods.

15 [Glass transition temperature (Tg)]

The glass transition temperature of a sample was measured at a heating rate of 20°C/min under a nitrogen atmosphere by means of a differential scanning calorimeter manufactured by Seiko Instruments Inc.

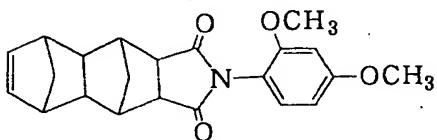
20 Number average molecular weight, weight average molecular weight and molecular weight distribution:

The number average molecular weight, weight average molecular weight and molecular weight distribution in terms of polystyrene of a sample were measured by "HLC-8020 Gel Permeation Chromatograph" manufactured by TOSOH CORP. using tetrahydrofuran as a solvent.

<Referential Example (Synthesis of Specific Monomer (I))>

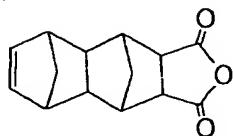
A 1-L three neck flask equipped with a reflux condenser was charged with 30 g (0.1303 mol) of 6-oxa-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the following structural formula (B) and 19.96 g (0.1303 mol) of 2, 4-dimethoxyaniline, and 300 mL of acetic acid was further added as a solvent. When this reaction system was heated, the reaction system became a homogeneous state. In this state, the reaction system was refluxed for 3 hours. After the reaction system was 10 allowed to cool, a removing treatment of acetic acid was conducted by an evaporator, and the residue was recrystallized from methanol to obtain 44.96 g (rough yield: 94%) of a reddish brown solid. The thus-obtained crystals were recrystallized from methanol, thereby 15 obtaining 19.74 g (yield: 41%) of a white solid. This white solid was identified as 6-(2,4-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the following structural formula (A). [Chemical formula 13]

20 Structural formula (A):



[Chemical formula 14]

Structural formula (B):



<Example 1>

5        A reaction vessel purged with nitrogen was charged with 7.90 g (21.6 mmol) of 6-(2,4-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the above structural formula (A) as Specific Monomer (I), 5.01 g (21.6 mmol) of 8-methyl-8-methoxy-10 carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene represented by the following structural formula (C) as Specific Monomer (II), 0.27 g of 1-hexene as a molecular weight modifier and 51.5 g of toluene as a solvent, and the contents were heated to 80°C. To this system, were added 0.13 mL of a toluene solution (0.6 mol/L) of triethylaluminum and 0.34 mL of a toluene solution (0.025 mol/L) of methanol-modified tungsten hexachloride as catalysts, and a reaction was conducted at 80°C for 4 hours, thereby obtaining a polymer solution containing a ring-opened polynorbornene.

15      The ring-opened polynorbornene thus obtained had a weight average molecular weight (Mw) of  $14.2 \times 10^4$ , a number average molecular weight (Mn) of  $3.38 \times 10^4$  and a molecular weight distribution (Mw/Mn) of 4.20.

[Chemical formula 15]

Structural formula (C) :



The resultant polymer solution was placed in an  
 5 autoclave, and 300 g of toluene was further added. As a  
 hydrogenation catalyst, RuHCl(CO) [P(C<sub>6</sub>H<sub>5</sub>)<sub>3</sub>]<sub>3</sub> was then added  
 in an amount of 2500 ppm to the charged amount of the  
 monomers in the reaction system to conduct a hydrogenation  
 reaction under conditions that a hydrogen gas pressure was  
 10 9 to 10 MPa, a reaction temperature was 160 to 165°C, and  
 the reaction conditions were 4 hours. After completion of  
 the reaction, the resultant reaction solution was poured  
 into a great amount of methanol to precipitate a product,  
 thereby obtaining a hydrogenated ring-opened polynorbornene.  
 15 This ring-opened polynorbornene is referred to as "Polymer  
 (P1)".

Polymer (P1) had a weight average molecular weight  
 (M<sub>w</sub>) of  $14.9 \times 10^4$ , a number average molecular weight (M<sub>n</sub>)  
 of  $3.59 \times 10^4$ , a molecular weight distribution (M<sub>w</sub>/M<sub>n</sub>) of  
 20 4.15, an intrinsic viscosity ( $\eta_{inh}$ ) of 0.74 and a glass  
 transition temperature (T<sub>g</sub>) of 221.4°C.

A proportion of the structural unit (I) derived from  
 6-(2,4-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.  
 0<sup>4,8</sup>]pentadec-12-ene-5,7-dione in Polymer (P1) was 44 mol%,  
 25 and a proportion of the structural unit (II) derived from

8-methyl-8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene was 56 mol%.

As a result that Polymer (P1) was analyzed by <sup>1</sup>H-NMR, it was found that the hydrogenation rate of the olefinic double bonds is at least 99%, and the remaining rate of the aromatic rings is substantially 100%. The <sup>1</sup>H-NMR spectrum and IR spectrum of Polymer (P1) are illustrated in Fig. 1 and Fig. 2, respectively.

<Example 2>

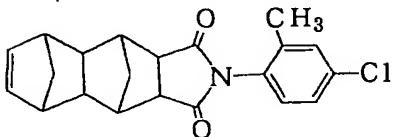
10 A reaction vessel purged with nitrogen was charged with 5.00 g (15.0 mmol) of 6-(4-chloro-2-methylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the following structural formula (D) as Specific Monomer (I), 3.48 g (15.0 mmol) of 8-methyl-8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene represented by the above structural formula (C) as Specific Monomer (II), 0.19 g of 1-hexene as a molecular weight modifier and 66 g of toluene as a solvent, and the contents were heated to 100°C. To this system, were added 0.16 mL 15 of a toluene solution (0.6 mol/L) of triethylaluminum and 0.44 mL of a toluene solution (0.025 mol/L) of methanol-modified tungsten hexachloride as catalysts, and a reaction was conducted at 80°C for 4 hours, thereby obtaining a polymer solution containing a ring-opened polynorbornene.

20 The ring-opened polynorbornene thus obtained had a weight average molecular weight (Mw) of  $10.7 \times 10^4$ , a number average molecular weight (Mn) of  $3.49 \times 10^4$  and a

molecular weight distribution (Mw/Mn) of 3.07.

[Chemical formula 16]

Structural formula (D) :



5 The resultant ring-opened polynorbornene was subjected to a hydrogenation reaction in the same manner as in Example 1, thereby obtaining a hydrogenated ring-opened polynorbornene. This ring-opened polynorbornene is referred to as "Polymer (P2)".

10 Polymer (P2) had a weight average molecular weight (Mw) of  $10.3 \times 10^4$ , a number average molecular weight (Mn) of  $3.50 \times 10^4$ , a molecular weight distribution (Mw/Mn) of 2.94, an intrinsic viscosity ( $\eta_{inh}$ ) of 0.58 and a glass transition temperature (Tg) of 215.0°C.

15 A proportion of the structural unit (I) derived from 6-(4-chloro-2-methylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione in Polymer (P2) was 37.2 mol%, and a proportion of the structural unit (II) derived from 8-methyl-8-methoxy-carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene was 62.8 mol%.

20 As a result that Polymer (P2) was analyzed by <sup>1</sup>H-NMR, it was found that the hydrogenation rate of the olefinic double bonds is at least 99%, and the remaining rate of the aromatic rings is substantially 100%. The <sup>1</sup>H-NMR spectrum and IR spectrum of Polymer (P2) are illustrated in Fig. 3

and Fig. 4, respectively.

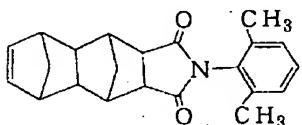
<Example 3>

A reaction vessel purged with nitrogen was charged with 5.00 g (14.1 mmol) of 6-(2,6-dimethylphenyl)-6-aza-  
5 pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione  
represented by the following structural formula (E) as Specific Monomer (I), 3.28 g (14.1 mmol) of 8-methyl-8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene  
represented by the above structural formula (C) as Specific  
10 Monomer (II), 0.20 g of 1-hexene as a molecular weight  
modifier and 34 g of toluene as a solvent, and the contents  
were heated to 80°C. To this system, were added 0.07 mL of  
a toluene solution (0.6 mol/L) of triethylaluminum and 0.24  
mL of a toluene solution (0.025 mol/L) of methanol-modified  
15 tungsten hexachloride as catalysts, and a reaction was  
conducted at 80°C for 0.5 hours, thereby obtaining a  
polymer solution containing a ring-opened polynorbornene.

The ring-opened polynorbornene thus obtained had a weight average molecular weight (Mw) of  $26.3 \times 10^4$ , a  
20 number average molecular weight (Mn) of  $3.35 \times 10^4$  and a molecular weight distribution (Mw/Mn) of 7.86.

[Chemical formula 17]

Structural formula (E) :



25 The resultant ring-opened polynorbornene was

subjected to a hydrogenation reaction in the same manner as in Example 1, thereby obtaining a hydrogenated ring-opened polynorbornene. This ring-opened polynorbornene is referred to as "Polymer (P3)".

5        Polymer (P3) had a weight average molecular weight (Mw) of  $26.0 \times 10^4$ , a number average molecular weight (Mn) of  $4.50 \times 10^4$ , a molecular weight distribution (Mw/Mn) of 5.78, an intrinsic viscosity ( $\eta_{inh}$ ) of 1.12 and a glass transition temperature (Tg) of 205.1°C.

10      A proportion of the structural unit (I) derived from 6-(2,6-dimethylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione in Polymer (P3) was 34.7 mol%, and a proportion of the structural unit (II) derived from 8-methyl-8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene was 65.3 mol%.

15      As a result that Polymer (P3) was analyzed by <sup>1</sup>H-NMR, it was found that the hydrogenation rate of the olefinic double bonds is at least 99%, and the remaining rate of the aromatic rings is substantially 100%. The <sup>1</sup>H-NMR spectrum and IR spectrum of Polymer (P3) are illustrated in Fig. 5 and Fig. 6, respectively.

<Example 4>

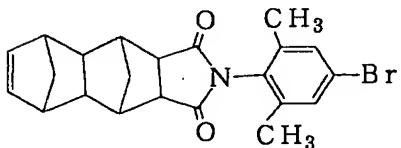
20      A reaction vessel purged with nitrogen was charged with 5.00 g (12.1 mmol) of 6-(4-bromo-2,6-dimethylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the following structural formula (F) as Specific Monomer (I), 2.80 g (12.1 mmol) of 8-methyl-8-

methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene represented by the above structural formula (C) as Specific Monomer (II), 0.15 g of 1-hexene as a molecular weight modifier and 31.2 g of toluene as a solvent, and the 5 contents were heated to 80°C. To this system, were added 0.12 mL of a toluene solution (0.6 mol/L) of triethylaluminum and 0.39 mL of a toluene solution (0.025 mol/L) of methanol-modified tungsten hexachloride as catalysts, and a reaction was conducted at 80°C for 3 hours, 10 thereby obtaining a polymer solution containing a ring-opened polynorbornene.

The ring-opened polynorbornene thus obtained had a weight average molecular weight (Mw) of  $11.2 \times 10^4$ , a number average molecular weight (Mn) of  $5.77 \times 10^4$  and a 15 molecular weight distribution (Mw/Mn) of 1.94.

[Chemical formula 18]

Structural formula (F) :



The resultant ring-opened polynorbornene was 20 subjected to a hydrogenation reaction in the same manner as in Example 1, thereby obtaining a hydrogenated ring-opened polynorbornene. This ring-opened polynorbornene is referred to as "Polymer (P4)".

Polymer (P4) had a weight average molecular weight

(Mw) of  $10.1 \times 10^4$ , a number average molecular weight (Mn) of  $4.41 \times 10^4$ , a molecular weight distribution (Mw/Mn) of 2.29, an intrinsic viscosity ( $\eta_{inh}$ ) of 0.56 and a glass transition temperature (Tg) of 225.3°C.

5 A proportion of the structural unit (I) derived from 6-(4-bromo-2,6-dimethylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione in Polymer (P4) was 36.6 mol%, and a proportion of the structural unit (II) derived from 8-methyl-8-methoxy-carbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene was 63.4 mol%.

10 As a result that Polymer (P4) was analyzed by <sup>1</sup>H-NMR, it was found that the hydrogenation rate of the olefinic double bonds is at least 99%, and the remaining rate of the aromatic rings is substantially 100%. The <sup>1</sup>H-NMR spectrum 15 and IR spectrum of Polymer (P4) are illustrated in Fig. 7 and Fig. 8, respectively.

<Example 5>

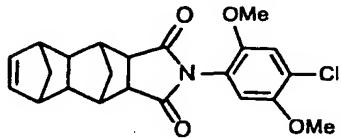
A reaction vessel purged with nitrogen was charged with 8.62 g (21.6 mmol) of 6-(4-chloro-2,5-dimethoxyphenyl)-20 6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the following structural formula (G) as Specific Monomer (I), 5.00 g (21.6 mmol) of 8-methyl-8-methoxycarbonyltetracyclo[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene represented by the above structural formula (C) as Specific 25 Monomer (II), 0.27 g of 1-hexene as a molecular weight modifier and 31.3 g of toluene as a solvent, and the contents were heated to 80°C.. To this system, were added

0.11 mL of a toluene solution (0.6 mol/L) of triethylaluminum and 0.35 mL of a toluene solution (0.025 mol/L) of methanol-modified tungsten hexachloride as a catalysts, and a reaction was conducted at 80°C for 4 hours, 5 thereby obtaining a polymer solution containing a ring-opened polynorbornene.

The ring-opened polynorbornene thus obtained had a weight average molecular weight (Mw) of  $15.8 \times 10^4$ , a number average molecular weight (Mn) of  $3.35 \times 10^4$  and a 10 molecular weight distribution (Mw/Mn) of 4.73.

[Chemical formula 19]

Structural formula (G) :



The resultant ring-opened polynorbornene was 15 subjected to a hydrogenation reaction in the same manner as in Example 1, thereby obtaining a hydrogenated ring-opened polynorbornene. This ring-opened polynorbornene is referred to as "Polymer (P5)".

Polymer (P5) had a weight average molecular weight 20 (Mw) of  $11.8 \times 10^4$ , a number average molecular weight (Mn) of  $3.69 \times 10^4$ , a molecular weight distribution (Mw/Mn) of 3.18, an intrinsic viscosity ( $\eta_{inh}$ ) of 0.50 and a glass transition temperature (Tg) of 215.0°C.

A proportion of the structural unit (I) derived from 6-(4-chloro-2,5-dimethoxyphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione in Polymer (P5) was 41.6 mol%, and a proportion of the structural unit (II) 5 derived from 8-methyl-8-methoxycarbonyltetracyclo-[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene was 58.4 mol%.

As a result that Polymer (P5) was analyzed by <sup>1</sup>H-NMR, it was found that the hydrogenation rate of the olefinic double bonds is at least 99%, and the remaining rate of the 10 aromatic rings is substantially 100%. The <sup>1</sup>H-NMR spectrum and IR spectrum of Polymer (P5) are illustrated in Fig. 9 and Fig. 10, respectively.

<Example 6>

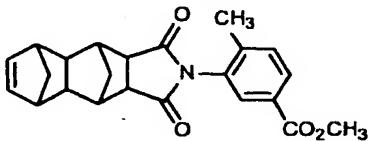
A reaction vessel purged with nitrogen was charged 15 with 5.00 g (12.1 mmol) of 6-(2-methyl-5-methoxycarbonylphenyl)-6-aza-pentacyclo[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione represented by the following structural formula (H) as Specific Monomer (I), 8.13 g (12.1 mmol) of 8-methyl-8-methoxycarbonyltetracyclo-[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene represented by the above 20 structural formula (C) as Specific Monomer (II), 0.27 g of 1-hexene as a molecular weight modifier and 120.8 g of toluene as a solvent, and the contents were heated to 80°C. To this system, were added 0.11 mL of a toluene solution 25 (0.6 mol/L) of triethylaluminum and 0.34 mL of a toluene solution (0.025 mol/L) of methanol-modified tungsten hexachloride as catalysts, and a reaction was conducted at

80°C for 4 hours, thereby obtaining a polymer solution containing a ring-opened polynorbornene.

The ring-opened polynorbornene thus obtained had a weight average molecular weight (Mw) of  $20.0 \times 10^4$ , a 5 number average molecular weight (Mn) of  $2.31 \times 10^4$  and a molecular weight distribution (Mw/Mn) of 8.66.

[Chemical formula 20]

Structural formula (H) :



10 The resultant ring-opened polynorbornene was subjected to a hydrogenation reaction in the same manner as in Example 1, thereby obtaining a hydrogenated ring-opened polynorbornene. This ring-opened polynorbornene is referred to as "Polymer (P6)".

15 Polymer (P6) had a weight average molecular weight (Mw) of  $26.5 \times 10^4$ , a number average molecular weight (Mn) of  $4.21 \times 10^4$ , a molecular weight distribution (Mw/Mn) of 6.30, an intrinsic viscosity ( $\eta_{inh}$ ) of 0.97 and a glass transition temperature (Tg) of 211.6°C.

20 A proportion of the structural unit (I) derived from 6-(2-methyl-5-methoxycarbonylphenyl)-6-aza-pentacyclo-[9.2.1.1<sup>3,9</sup>.0<sup>2,10</sup>.0<sup>4,8</sup>]pentadec-12-ene-5,7-dione in Polymer (P6) was 44.1 mol%, and a proportion of the structural unit

(II) derived from 8-methyl-8-methoxycarbonyltetracyclo-[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene was 55.9 mol%.

As a result that Polymer (P6) was analyzed by <sup>1</sup>H-NMR, it was found that the hydrogenation rate of the olefinic 5 double bonds is at least 99%, and the remaining rate of the aromatic rings is substantially 100%. The <sup>1</sup>H-NMR spectrum and IR spectrum of Polymer (P6) are illustrated in Fig. 11 and Fig. 12, respectively.

<Comparative Example 1>

10 A reaction vessel purged with nitrogen was charged with 50 g of 8-methyl-8-methoxycarbonyltetracyclo-[4.4.0.1<sup>2,5</sup>.1<sup>7,10</sup>]dodec-3-ene represented by the above structural formula (C) as a monomer, 3.6 g of 1-hexene as a molecular weight modifier and 100 g of toluene as a solvent, 15 and the contents were heated to 80°C. To this system, were added 0.09 mL of a toluene solution (0.6 mol/L) of triethylaluminum and 0.29 mL of a toluene solution (0.025 mol/L) of methanol-modified tungsten hexachloride as catalysts, and a reaction was conducted at 80°C for 3 hours, 20 thereby obtaining a polymer solution containing a ring-opened polynorbornene.

The resultant ring-opened polynorbornene was subjected to a hydrogenation reaction in the same manner as in Example 1, thereby obtaining a hydrogenated ring-opened 25 polynorbornene. This ring-opened polynorbornene is referred to as "Polymer (P7)".

Polymer (P7) had a weight average molecular weight

(M<sub>w</sub>) of  $5.6 \times 10^4$ , a number average molecular weight (M<sub>n</sub>) of  $1.75 \times 10^4$ , a molecular weight distribution (M<sub>w</sub>/M<sub>n</sub>) of 3.2 and a glass transition temperature (T<sub>g</sub>) of 167°C.

As a result that Polymer (P7) was analyzed by <sup>1</sup>H-NMR,  
5 it was found that the hydrogenation rate of the olefinic  
double bonds is at least 99%.

<Evaluation>

Polymer (P1) to Polymer (P7) obtained in Examples 1 to 6 and Comparative Example 1 were separately dissolved in  
10 toluene or methylene chloride, thereby preparing solutions for solvent casting. Each of these solutions was placed on a glass plate and subjected to a drying treatment, thereby producing a colorless and transparent film having a thickness of 200  $\mu\text{m}$  and a residual solvent of 0.5 to 0.8%.

15 The films thus obtained were respectively uniaxially stretched at their corresponding stretching ratios shown in the following Table 1, thereby producing stretched films. The stretching temperature was T<sub>g</sub> + 10°C, in which T<sub>g</sub> was a glass transition temperature of the polymer forming the  
20 film. The birefringence  $\Delta n$  ( $\Delta n = n_x - n_y$ ; n<sub>x</sub>: refractive index in a stretching direction; n<sub>y</sub>: refractive index in a direction perpendicular to the stretching direction) of each of the resultant films was measured by means of an automatic birefringence analyzer "KOBRA21DH" manufactured  
25 by Oji Scientific Instruments. Birefringence values at a measuring wavelength of 550 nm are shown in Table 1.

[Table 1]

	Glass transition temperature (°C)	Stretching ratio (times)	Birefringence $\Delta n$ (550nm)
Example 1	221.4	1.7	$5.0 \times 10^{-4}$
Example 2	215.0	1.7	$12.0 \times 10^{-4}$
Example 3	205.1	1.4	$6.4 \times 10^{-4}$
Example 4	225.3	2.0	$-0.3 \times 10^{-4}$
Example 5	215.0	1.7	$5.5 \times 10^{-4}$
Example 6	211.6	1.7	$9.3 \times 10^{-4}$
Comparative Example 1	167.0	1.7	$31.4 \times 10^{-4}$

As apparent from Table 1, it was confirmed that the  
 5 stretched films formed respectively of Polymers (P1) to  
 (P6) according to Examples 1 to 6 are all lower in  
 birefringence than the stretched film formed of Polymer  
 (P7) according to Comparative Example 1. In particular,  
 the stretched film formed of Polymer (P4) according to  
 10 Example 4 scarcely exhibited birefringence.

With respect to the stretched film formed of Polymer  
 (P1) according to Example 1 and the stretched film formed  
 of Polymer (P7) according to Comparative Example 1,  
 retardation ( $Re = \Delta n \times d$ ; d: thickness of the film) was  
 15 measured by means of the automatic birefringence analyzer  
 "KOBRA21DH" manufactured by Oji Scientific Instruments to  
 find values of a ratio  $Re/Re550$  of retardation  $Re$  at  
 respective wavelengths to retardation  $Re550$  at a wavelength

of 550 nm. The result is shown in Fig. 13.

As apparent from Fig. 13, it was confirmed that the value of the ratio  $Re/Re_{550}$  of the stretched film formed of Polymer (P1) according to Example 1 becomes greater as the wavelength of transmitted light becomes longer, and so the dependence of birefringence on wavelength is high and specific.

On the other hand, the value of the ratio  $Re/Re_{550}$  of the stretched film formed of Polymer (P7) according to 10 Comparative Example 1 was almost constant irrespective of the wavelength of transmitted light.